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Charcoal analysis and the reconstruction of ancient woodland vegetation in the Konya Basin, south-central Anatolia, Turkey: results from the Neolithic site of Çatalhöyük East

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Abstract. The results produced by charcoal analysis are used in conjunction with pollen evidence, geomorphological data and ecological analogues, in order to reconstruct ancient woodland vegetation in the Konya Basin and its surroundings during the Neolithic. Emphasis is placed on the structure, diversity and seasonal habit of different vegetation types, as well as their potential response to natural and/or anthropogenic disturbance. It is argued that such an approach to vegetation reconstruction enables better insights into palaeoenvironments as experienced by human groups in the past, and thus offers fruitful avenues for investigating the relationship of human societies with the natural environment.

Key words: Archaeobotany – Charcoal analysis – Anatolia – Neolithic – Turkey

Introduction

One of the major objectives of charcoal analysis is the reconstruction of past vegetation. For dry land environments this aspect is very important, since other sources of evidence usually provide a palaeoenvironmental record that rarely, if at all, meets the standards set for temperate environments. This is a customary situation in the eastern Mediterranean and the Near East, where palynological investigations have difficulties with discontinuous pollen sequences, poor pollen preservation and inadequate chronological resolution.

However, current approaches to vegetation reconstruction in this part of the world differ substantially from their counterparts in more temperate regions. Hence, in Europe there is a long-standing tradition in studying woodland management and its implications for the creation and maintenance of cultural landscapes (for example Rackham 1976; Behre 1988; Rasmussen 1989; Kreuz 1992; Simmons and Innes 1996; Halstead et al. 1998). Contrary to this, in southwest Asia the principal objective for reconstructing early Holocene environments has been the investigation of past climate change as reflected in the pollen and plant macrofossil record (for example Bottema 1987, 1995; Van Zeist and Bottema 1991; Willcox 1992). One reason for this difference in approach may be the traditional emphasis given to the study of food plants. As a result of this, woodlands are perceived primarily as the "environmental backdrop" in a discourse otherwise concerned with the distribution of wild progenitors and the ecological settings of early plant husbandry (see Zohary and Hopf 1988; McCorriston 1992; Hillman 1996). Furthermore, ecological studies in the Near East are dominated by approaches that tend to favour the somewhat static phytosociological descriptions of floristic associations rather than the more dynamic aspects of community ecology (for example Zohary 1973).

Our research aims at reconstructing ancient vegetation and its utilisation by human communities residing in the Konya Basin during the Neolithic period, by integrating the charcoal evidence with data produced by ongoing archaeological and palaeoecological investigations. An essential step towards this direction, and the focus of the present paper, is the reconstruction of past vegetation in terms of its structure, diversity and seasonal habit and its potential responses to natural and/or anthropogenic disturbance.

The study area

The Konya Basin lies on the southern edge of the Central Anatolian Plateau, at an elevation of ca. 1000 m asl. It forms an internally drained depression encircled by mountains, to the north and east by the Anatolides chain and to its southern fringes by the Taurus range. Near the centre of the basin, the isolated volcanic massif of Karadağ rises from the nearly flat plain to an elevation of 2271 m. Two further extinct volcanoes, Alacadağ and Bozdağ, dominate its west and north-west borders.

Numerous watercourses enter the basin from the surrounding uplands, particularly from its south and south-west fringes, giving rise to backswamps, marshes, minor lakes and extensive fans of alluvial origin. It is on these alluvial fans that some of the most important Neolithic set-

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tlements in this part of Anatolia are located (see also Fig. 1): Çatalhöyük East and Can Hasan III on the Çarşamba and Selerecki fans respectively (Mellaart 1962; French et al. 1972; Hodder 1996). In contrast, the Neolithic open air site and the rock-shelter of Pınarbaşı lie at the base of a limestone ridge nearby the foothills of Karadağ, next to what was until recently a small, spring-fed lake surrounded by seasonally flooded reed-marshes (Watkins 1996).

Besides alluvial formations, the basin floor comprises a variety of sedimentary deposits. These consist primarily of limestone of lacustrine origin, formed during the Neogene and representing the now-drained floor deposits of a palaeolake; aeolian sands, relict shoreline deposits, cliffs and dunes testify to its former extent (De Ridder 1965; Erol 1978, pp 127-128). Overlying these limestone deposits are gravel, sand, clay and marl which accumulated during the Quaternary, thus gradually infilling the basin floor. Towards the fringes of the basin and along the foothills of the surrounding uplands, clastics give way to steep colluvial slopes alternating with gently undulating piedmont plains (alluvial deposits at the foot of mountains) and remnants of the Neogene limestone terraces (De Meester 1971, p 8).

Descriptions of present-day vegetation in central Anatolia and the Konya plain point towards a predominantly steppic vegetation (De Meester 1970, pp 34-35; see also Davis 1965-1988; Kayacik and Yaltirik 1971; Zohary 1973). Steppe elements include *Artemisia* spp. (wormwood), several species of *Stipa* and spiny *Astragalus*, *Noaea mucronata*, *Alhagi camelorum* and *Peganum harmala*. In those parts of the plain that are strongly affected by salinization, halophytic chenopods prevail, whilst reeds and rushes flourish in marshlands. Only protected sites and the relatively well-drained marginal areas such as terraces, bajadas (piedmont alluvial plains formed by the coalescence of several alluvial fans) and colluvial slopes are able to support extensive, species-rich grasslands (Cohen 1970, p 123; De Meester 1970, p 34). Trees and scrub are restricted to the upland zone. On the north-facing slopes of the Taurus mountain range one may

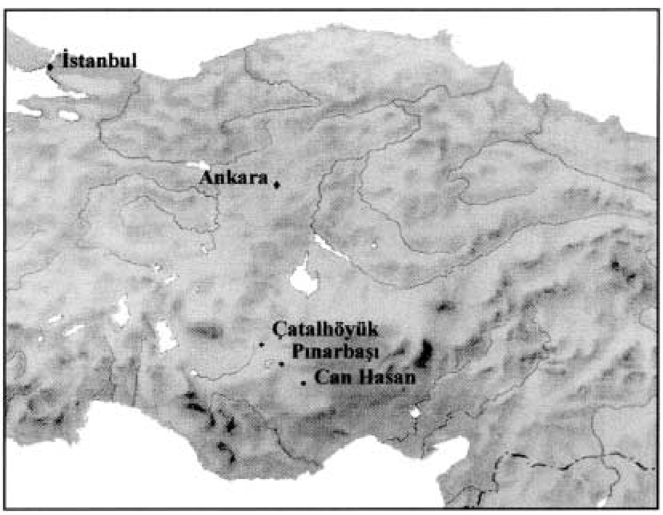

Fig. 1. Map showing the location of the archaeological sites mentioned in the text

encounter relics of the formerly extensive Xero-Euxinian open oak forests (*Quercus macrolepis*, *Q. trojana*), frequently reduced by woodcutting and browsing to thickets of brushwood under a canopy of *Pinus nigra* (black pine). Other elements of the Xero-Euxinian woodland include *Abies cilicica* (fir) and *Juniperus excelsa* (juniper). Junipers may reach the periphery of the inner Anatolian steppe zone, sometimes accompanied by oaks and *Celtis tournefortii* (hackberries). Minor elements comprise several rosaceous trees and shrubs, such as *Crataegus orientalis* and *C. laciniata* (hawthorns), *Amygdalus orientalis* (almond), *Cerasus (Prunus) microcarpa*, *C. prostrata* and *C. mahaleb* (cherries) together with *Pyrus elaeagrifolia* and *P. amygdaliformis* (wild pears).

The mean annual precipitation on the plain ranges between 260 and 300 mm, being almost evenly distributed throughout autumn, winter and spring. Rainfall is more frequent during the spring months, and it snows in winter. In general, evaporation exceeds precipitation on the plain itself, whereas higher elevations are wetter, with maxima of up to 1000 mm of mean annual rainfall recorded for the Taurus chain. Temperatures may vary between 0°C during winter and 22°C in summer. Extreme values of -25°C and over 35°C have also been reported. The average number of days with temperatures below 0°C is 103.3 for the area of Konya and 97.6 for the area of Çumra, occurring in autumn, winter and early spring (De Meester 1970, table 1).

The site and its archaeological context

Çatalhöyük East is a large tell site, the Neolithic occupation of which spans some 1000 years (the available radiocarbon dates indicate a period between ca. 8200 uncal. B.P. and 7600 uncal. B.P., cf. Todd 1976, pp 100-101 with the early, pre-level X deposits as yet undated). The account of the archaeological evidence that follows has been based on the information provided by Mellaart (1962, 1967), Hodder (1996) and the web pages of Çatalhöyük Archive Report (1996, 1997, 1998, 1999). To date, the excavations have unearthed an assortment of closely spaced mud-brick houses, furnished with storage bins, ovens, hearths and platforms and separated by narrow passages and/or open spaces. The latter were used, together with abandoned structures, primarily for the disposal of refuse. The subsistence economy includes all those traits usually associated with the Neolithic such as the cultivation of cereals and pulses and herding of sheep, goats and probably cattle. Nevertheless, the faunal data seem to suggest that both wild and domesticated forms are present. Wild game apparently played a minor role in the diet. Archaeobotanical investigations have also shown the dependence of the local community on foods collected from the wild, such as *Celtis* (hackberry), *Pistacia* (pistachio) and *Amygdalus* (almond) and, presumably, the gathering of tubers in the local marshlands. A wide range of raw materials, such as obsidian, bone, skin, marble, stone, metal ores, sea-shells, clay, etc. were obtained in the course of everyday activities, either as finished objects or for manufacturing purposes. Wood apparently played an important role in the life of the settlement, as it provided not only fuel, but also timber for the construction of

Table 1. List of the taxa present in the charcoal assemblages and their relative frequencies calculated by fragment count and ubiquity (presence)

Year excavated	1996/97				1999			
excavated levels	V-VIII				pre-XII			
No. of samples examined	23				23			
No. of fragments examined	3325				2717			
	Absolute fragment count	%	ubiquity (no. of samples)	%	absolute fragments count	%	ubiquity no. of samples	%
Salicaceae indet.	250	7.52%	20	87%	396	14.57%	23	100%
Alnus	13	0.39%	5	22%	-	-	-	-
Vitex	7	0.21%	4	17%	4	0.15%	3	13%
Tamarix	6	0.18%	4	17%	-	-	-	-
Fraxinus	19	0.57%	9	39%	3	0.11%	2	9%
Ficus cf. *carica*	2	0.06%	2	9%	-	-	-	-
cf. *Clematis*	1	0.03%	1	4%	-	-	-	-
cf. *Platanus*	2	0.06%	2	9%	-	-	-	-
Ulmus	75	2.26%	18	78%	4	0.15%	4	17%
Celtis	104	3.13%	19	83%	171	6.29%	22	96%
Ulmaceae indet.	105	3.16%	20	87%	189	6.96%	23	100%
Anacardiaceae indet.	-	-	-	-	8	0.29%	7	30%
Ulmaceae/*Pistacia*	1	0.03%	1	4%	1	0.04%	1	4%
Pistacia	67	2.02%	18	78%	27	0.99%	12	52%
Maloideae indet.	83	2.50%	14	61%	42	1.55%	13	57%
Rosaceae indet.	-	-	-	-	1	0.04%	1	4%
Amygdalus	32	0.96%	13	57%	15	0.55%	13	57%
Prunus	20	0.60%	11	48%	-	-	-	-
Rosa	9	0.27%	6	26%	-	-	-	-
Chenopodiaceae indet.	14	0.42%	10	43%	5	0.18%	4	17%
Asteraceae indet.	18	0.54%	10	43%	14	0.52%	9	39%
Artemisia	8	0.24%	5	22%	3	0.11%	3	13%
Lamiaceae indet.	18	0.54%	11	48%	1	0.04%	1	4%
Fabaceae indet.	72	2.17%	18	78%	6	0.22%	3	13%
Colutea	16	0.48%	10	43%	-	-	-	-
Genista	10	0.30%	3	13%	-	-	-	-
Capparis	4	0.12%	3	13%	1	0.04%	1	4%
Quercus (deciduous)	1512	45.47%	23	100%	780	28.71%	22	96%
Acer	4	0.12%	3	13%	-	-	-	-
Caprifoliaceae indet.	3	0.09%	2	9%	-	-	-	-
Gymnosperms	6	0.18%	6	26%	-	-	-	-
Juniperus	138	4.15%	21	91%	10	0.37%	6	26%
Pinus cf. *nigra*	1	0.03%	1	4%	-	-	-	-
Indet.	705	21.20%	23	100%	1036	38.13%	23	100%
Total	**3325**	**100%**	**23**	**100%**	**2717**	**100%**	**23**	**100%**

houses and the raw material for the manufacture of various types of vessels and utensils.

Bearing in mind the enormous contextual variability encountered during excavation, a series of deposits was selected for sampling and analysing for wood charcoals. For the purpose of vegetation reconstruction, the samples presented here were taken from open areas that were used primarily for the disposal of refuse. The underlying assumption is that such deposits are more likely to represent the accumulated remains not only of wood collected as fuel, but also "secondary" fuels, such as the by-products of fodder and food consumption, wood working, defunct timber and wooden artefacts. Therefore, potential biases in taxon representation introduced by context-related variation are, to some extent at least, minimised. In this category of selected material fall flotation samples taken from the later levels of habitation excavated during the 1996/97 seasons and are roughly equivalent to Mellaart's levels V-VIII (for a discussion of stratigraphy, see Mellaart 1967 and especially S. Farid in Çatalhöyük Archive Report 1998, 1999). They mostly comprise slowly deposited material, appearing during excavation as discrete lenses of waste, with few if any signs of weathering and post-depositional disturbance. Further, a second group of samples were chosen from the deep sounding opened during the 1999 season, from the pre-level XII strata. These comprise a mixture of refuse deposits more akin to those included in the first group, and what the excavators have identified as the remains of in situ burnings for lime production.

The archaeobotanical evidence

For charcoal analysis, choosing a suitable subsampling strategy involves reaching a decision on the number and size range of fragments to be examined (Smart and Hoffman 1988). In practice, such a decision should allow recovery of an adequate charcoal flora, without at the same time compromising the need for the examination of as many samples as possible within the available time. In principle, a number of 100 fragments are considered as the minimum requirement for obtaining a satisfactory assessment of the sample composition (Keepax 1988). This limit was observed for the 4 mm fraction of each sample obtained through the dry sieving of the flots. In addition, up to 100 fragments from the respective 2 mm fraction were examined, in order to trace small woods such as shrubs and twiggy material.

Charcoal specimens were examined using the standard preparation techniques and microscopy procedures described by Leney and Casteel (1975). Identifications were made by comparison with reference material, inclu-ding the C.A. Western wood reference collection held at the Institute of Archaeology, University College London, and specimens collected in the field, as well as by using the standard keys used for wood identification in Europe and the Near East (for example Greguss 1959; Brazier and Franklin 1961; Fahn et al. 1986; Schweingruber 1990).

A comprehensive list of the taxa present in the charcoal assemblages is given in Table 1, together with their relative frequencies recorded as absolute/percentage fragment counts and ubiquity (presence scores). Quantitative results for the principal taxa are also displayed graphically in Figs. 2a and 2b. For the purpose of environmental reconstruction in particular, tabulating charcoal results in the form of presence/absence scores allows the assessment of past vegetation entities without depending so much on the interference of anthropogenic factors, such as routine practices and cultural preferences, that have almost certainly impacted on the absolute fragment frequencies observed for each taxon. Other methods of numerical analysis, such as absolute and percentage counts, share the disadvantage of relying overwhelmingly on fragment numbers and therefore disregard further biases introduced by differential fragmentation and mass reduction resulting from wood combustion (cf. Smart and Hoffman 1988).

Cultural selection and exposure to fire are but a few of the taphonomic factors shaping the composition of a wood charcoal assemblage. The abundance of each particular taxon is also related to the physical characteristics of wood prior to charring, such as age, shape, dimensions, season of gathering or occurrence of fungal decay. One important implication is that charcoal fragments of naturally small-sized taxa such as those from shrubs, or those collected mainly as dead wood, are likely to be under-represented in the archaeobotanical assemblages. The same phenomenon applies to charcoal derived from twigs and branches of immature forms of the larger trees and shrubs. The size of the charcoal fragments eventually retrieved is also influenced by recovery techniques. For flotation in particular, experimental work on its effects upon wood charcoal has demonstrated that the various physical stresses incurred during sample processing influence not only the range of taxa present within an assemblage, but also the actual quantity of each taxon and the fragment size ratios (Greenlee 1992).

However, since presence analysis inhibits any evaluation of the actual abundance of each taxon within individual samples, it was deemed necessary to employ fragment counts as a means for estimating these extant values for each group of samples (see Table 1, Fig. 2b). It also remains valid that alternative quantification methods (such as ratios, weights, absolute counts, etc.) can under certain circumstances sustain a more precise description of patterns associated with *wood use*, even more so in areas characterised by diverse vegetation mosaics. More specifically, they may give valuable insights concerning the amount and types of fuel (such as kindling as opposed to firewood proper), how intensively they were used,

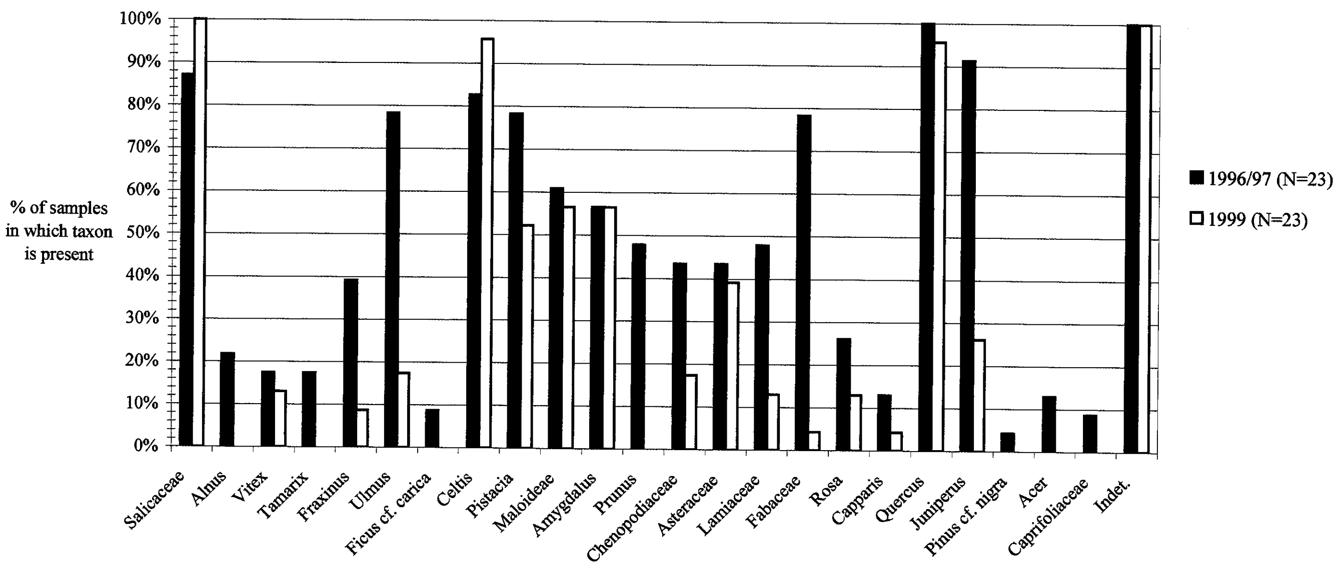

Fig. 2a. Taxonomic frequencies of the principal taxon groups calculated through ubiquity analysis (N=number of samples)

modes of wood procurement and utilisation, distribution within the different depositional contexts, etc. For a detailed discussion of the relative merits of each quantification method and their applications, see Willcox (1974), Miller (1985), Smart and Hoffman (1988) and Chabal (1992).

A closer inspection of the archaeobotanical results shows that the highest taxonomic diversity has derived from samples belonging to the later phases of the settlement. A series of taxa, namely *Acer* (maple), *Pinus* (pine), *Tamarix* (tamarisk), *Ficus* cf. *carica* (fig), *Rosa* (rose), Caprifoliaceae (members of the honeysuckle family) and *Prunus*-diffuse porous type (cherries) appear exclusively in the later levels. Concerning *Prunus*, it important to explain the distinction between the different charcoal identification types; it is hardly possible to identify *Prunus* charcoal to species level (Schweingruber 1990). The identification difficulty was increased by the small size and low frequencies of the charcoal fragments. However it was still possible to separate the diffuse porous group of taxa (including *P. avium*, *P. cerasus*, *P. mahaleb* and *P. spinosa)* from the ring porous taxa (including *Amygdalus* spp.).

The earlier levels, on the other hand, are marked by a decline of *Juniperus* (juniper) scores and the reduced abundance of certain riverine taxa such as *Ulmus* (elm) and *Fraxinus* (ash). Perhaps the most striking difference between the two assemblages is the discrepancy in the scores of shrubs such as Fabaceae (woody legumes), Lamiaceae (mint family), Chenopodiaceae (chenopods) and Asteraceae (wormwood family), which again are much higher towards the later levels. Overall, the archaeobotanical evidence seems to suggest the progressive expansion of coniferous taxa, notably juniper, accompanied by a rise in light-demanding shrubs and steppic elements such as rose, cherries, woody legumes, wormwoods, labiates and chenopods. The implications of these observations for the reconstruction of past vegetation and its evolution through time in relation to the palaeoenvironmental record and the ecological analogues currently available for similar environments, are treated in the later part of this paper.

Discussion

Recent palaeoecological research has significantly enriched our knowledge of the diversity of landscape settings encountered by the Neolithic inhabitants of the Konya plain. Through on-site geomorphological investigations (Roberts 1991; Roberts et al. 1996) it became evident that both the major Neolithic settlements of Çatalhöyük East and Can Hasan III were founded on alluvial fans that had started to accumulate at the onset of the Holocene. Detailed studies of the sedimentary sequences on and around the Neolithic mound of Çatalhöyük point towards the existence of various local microenvironments, ranging from active and abandoned river channels to seasonally submerged stretches of marshland and backswamps.

Vegetation surveys of comparable wetland environments throughout the Near East (compare Zohary 1962, 1973; Hillman 2000) indicate that they may serve as a host for distinct hygrophilous plant communities. The structure and floristic composition of the latter are primarily controlled by the different flooding regimes characterising the various parts of the alluvial plain. The most conspicuous effect of the river action would be the creation of distinct landforms, such as levées, ridges, islands, oxbow lakes, ponds and backswamps, thus determining at large the pat-

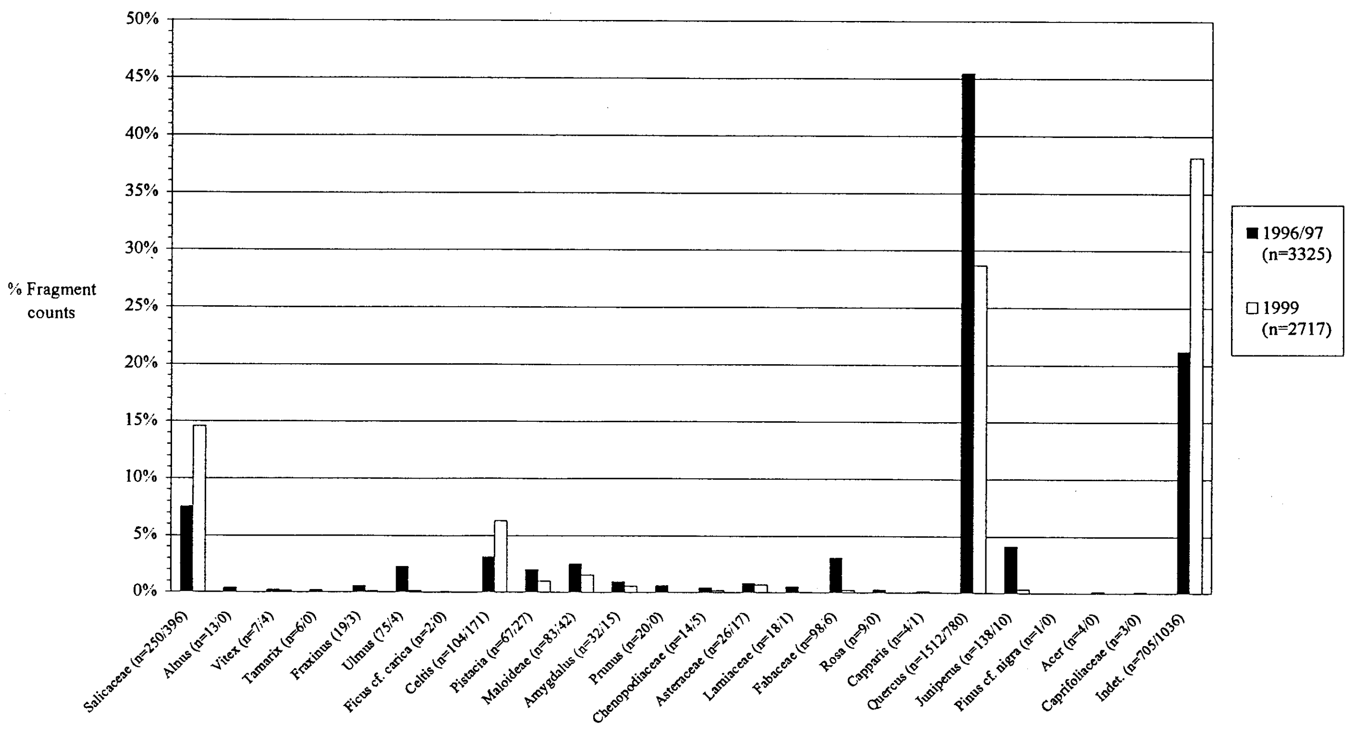

Fig. 2b. Taxonomic frequencies of the principal taxon groups displayed as percentages of the total number of fragments for each group of samples (n=number of fragments)

tern of tree communities. Generally, *Populus* (poplars), *Salix*-Salicaceae (willows), *Fraxinus* (ash) and *Tamarix* (tamarisk) together with woody climbers such as *Clematis* tend to form riparian gallery forests on alluvial flats, whilst *Platanus* (plane) trees and *Ulmus* (elm) can occur on better-drained localities towards the margins of the plain. On more sandy and gravelly exposures (such as levées and ephemeral streams) *Vitex* (chaste trees) and *Capparis* (capers) may abound. Tamarisks and poplars in particular demonstrate an ability to withstand saline conditions (Le Houérou 1985). Tamarisks especially can occupy a variety of habitats such as sandy shores, abandoned channels and brackish ponds due to their deeply penetrating and laterally extensive rootstock. On the other hand, shallow-rooted halophytes, for example certain species of Chenopodiaceae and Asteraceae, can thrive on periodically exposed riverbeds and saline depressions (Zohary and Orshansky 1949). The periodically submerged backswamps and other inundated surfaces present a very different picture. Here, high concentrations of organic matter accompanied by slow decomposition rates due to waterlogging tend to favour the growth of extensive stands of monocotyledonous grasses, reeds and rushes such as *Phragmites*, *Scirpus*, *Cyperus*, *Typha*, etc. Anaerobic conditions are also advantageous to those few trees such as *Alnus* that are able to fix nitrogen directly through their root system (Brown 1997, p 112).

As mentioned before, floodplain environments are subject to periodic disturbance brought about mainly by the different river regimes alternating on a seasonal basis. A typical scenario in this part of the world would involve a relatively high frequency of flooding episodes during autumn and winter, coupled with a strong decrease in temperature and a concomitant rise in snow cover and frost. In early spring, snow meltwater together with sudden rainstorms could also result in extensive overbank flooding. Floods usually have a direct effect on the vegetation structure and the regeneration process within riverine woodlands by depositing silt and nutrients, scouring floodplains and channel margins and washing out seeds and saplings (Peterken 1996, p 109). With the advent of the dry season (from late spring until autumn), the lowering of the water table would follow the creation of new patches of riparian woodland, through the re-seeding of the freshly exposed, nutrient-rich, alluvial flats. Increased animal activity around the progressively diminishing water bodies might also have multiple effects on the existing vegetative cover, through trampling, burrowing, deposition of excrement and browsing.

Likewise, woodcutting plays an important role in riverine woodland regeneration, since most of the associated biomass production increases as a result of coppicing and/or pollarding (cf. Rackham 1976, Table 1 and pp 20-22). In the long term, repeated gathering of firewood from riparian woodlands may lead to dominance by shrubs, thus transforming riverine woods to impenetrable scrub (Zohary 1973).

Woodland regrowth could have been further enhanced by clearing patches of vegetation and the removal of rotten stumps and vestiges of dead trees and shrubs. Settlement location seems to suggest that cultivation most probably took place on the alluvial flats instead of the better-drained hill slopes. Therefore, the establishment of new fields must have required at least some small-scale clearance of the riverine vegetation. Moreover, detailed microscopic examination of the wood charcoals has revealed that many of the fragments of hygrophilous taxa bore signs of fungal decay, thus probably signifying their collection as dead wood (cf. Salisbury and Jane 1940). Abundant gummy deposits in the vessel elements were observed, a phenomenon attributed, among other causes, to the sealing of abscission marks on trunks caused by the shedding of branches (Millington and Chaney 1973). However, the possibility of increased dead wood availability might equally apply to the height of the dry season in mid-summer, when shedding of shoots and branches serves the purpose of alleviating excessive moisture loss (Zohary and Orshansky 1949).

It is more difficult to reconstruct specific vegetation types for the rest of the Konya plain and the surrounding uplands, partly due to the lack of site-specific palaeoenvironmental records. The charcoal evidence from Can Hasan III, albeit incompletely published, indicates nonetheless the existence of a vegetation mosaic which included riverine taxa such as *Ulmus*, Salicaceae and *Fraxinus,* dry land indicators such as *Celtis*, *Amygdalus*, *Juniperus*, *Pistacia*, *Rosa* and Maloideae, and more moisture-dependent elements such as *Quercus* and *Pinus* (Willcox 1977, 1978, 1991). It seems probable that such diverse and potentially highly localised microenvironments are also related to the general climate patterns postulated for the early Holocene in this part of the Near East. Palaeoecological and climatic research indicates that the general trend was towards increased seasonality during the Neolithic period, with maximum temperatures and hence intense drought occurring during the dry season, whereas higher precipitation characterised the winter months (Byrne 1987; COHMAP Members 1988; Rossignol-Strick 1999).

Such a climatic regime, with pronounced local and seasonal variations in annual rainfall, must have exerted a direct effect on the shape, structure and location of vegetation types. In the drier areas of the plain, further modifications on the timing and intensity of rainfall could have been induced by topography and soil properties, thus giving rise to a discontinuous, patchy and highly diversified vegetative cover (Wiens 1985).

It is possible to distinguish two major landscape entities, based on rainfall distribution, relief and soil properties: first, the upland zone, comprising the northern exposures of the Taurus range, the volcanic and limestone uplands, and the colluvial slopes and bajadas on the foothills of the mountains, and secondly the flat lacustrine sediments taking over towards the interiors of the plain.

Some of the coniferous taxa present in the charcoal assemblages, as for example *Pinus*, are only found in this area now on the higher slopes of the Taurus range. Here, *P. nigra* has been reported forming dense stands in mid-elevation slopes together with *Quercus macrolepis, Q. trojana*, *Juniperus excelsa* and *J. oxycedrus* (Zohary 1973; Van Zeist et al. 1975). During the Neolithic, limiting conditions for the full development of montane coniferous woods prevailed until around 8,000 B.P., as shown in the pollen diagrams mainly from southwestern Anatolia (Van Zeist et al. 1975; Eastwood et al. 1999).

In the lower upland zone, most of which today receives around 400 mm precipitation (De Meester 1970: Fig. 13), pine and oak could have co-existed alongside drought resistant taxa, such as *Juniperus*, *Acer*, woody Fabaceae, *Prunus*, and other heliophilous undershrubs thriving in natural openings and cleared spaces (Zohary 1973; Le Houérou 1985). Such open and semi-open woods might have developed on the limestone uplands and the reddish-brown soils (weathered limestone, in places deep and well drained, resembling the Mediterranean terra rossa) concentrated mainly south of Konya (De Meester 1971). In the long term, any radical alterations in the structure and composition of such plant communities are critically dependent on human intervention. The prolonged use of these areas as grazing grounds may lead to the expansion of conifers, with detrimental effects on the more palatable broadleaved taxa. The shade intolerant pines and junipers compete successfully and often replace oaks and broadleaved undershrubs as the dominant elements, under conditions of intense browsing and/or selective logging because of more successful seedling establishment (Zohary 1962, 1973).

Extensive oak forests might also have developed in protected micro-sites on the upland zone. Ecological investigations in the Karadağ area (Ocakverdi and Ünal 1991) indicate that, until recently, deep volcanic soils in the bottoms of valleys located on north-eastern slopes, could sustain very dense deciduous oak woods with *Quercus vulcanica* (Davis et al. 1965-8, vol. 7, p 670). Due to the inability of light to penetrate the woodland canopy and the closely spaced tree trunks, oaks were reported to attain a thin straight shape and shed their lateral branches at regular intervals. Intensive cutting for firewood during the last decade and frequent pest outbreaks have reduced these valley forests to scattered patches of sparse oak scrub.

On the southern exposures of volcanic slopes, at the foothills of the mountains surrounding the Konya plain and the low limestone ridges and hills raising from the plain itself (~300 mm of mean annual rainfall), open park-like woodland could grow, with a wide array of winter deciduous trees and shrubs which usually grow in open habitats, and are moreover resistant to extreme dry and cold conditions (cf. Zohary 1973; Hillman 2000). These include various oaks, pears and hawthorns, cherries, almonds, hackberries, pistachios, shrubby junipers, and the occasional fig shrubs in rocky outcrops, near sources of fresh water.

During spring and early summer, from late March until June, park woodland would reach its full vegetative development, with most of the trees and bushes coming into flower and lush stands of perennial and annual grasses forming a dense ground cover. The fruit season would then follow, from late spring until the end of summer and occasionally up to mid-autumn, as is the case with hawthorns and, less so, pistachios. At this time of the year, the herbaceous cover would die off, hence leading to the accumulation of large quantities of dry litter on the woodland floor. This would eventually turn into a ground layer of slowly decomposing dark herbaceous litter during the wet season in autumn and the ensuing winter months. On the other hand, the resilient nature of the park woodland trees and shrubs would inhibit the shedding of lateral branches and shoots, unless the plants had already completed their life cycle (G. Hillman, personal communication).

Towards the drier interiors of the plain, where mean annual rainfall rarely exceeds 200 mm and winter frosts are frequent, the dominant vegetation formations were probably more akin to steppe, with perennial chenopods, wormwoods and various aromatic shrublets of the Lamiaceae (mint family) alternating with stretches of grassland. In places, as for example on limestone outcrops and chalky clays, nearby alluvial plains and at the fringes of hill slopes abutting park-woodland, "islands" of xerophytic tree communities might have arisen. The closest present-day ecological parallels are represented by woodland-steppe in northeast Syria, in the area of Jebel Abdul Aziz (Hillman 2000) and in southern Jordan (Kürschner 1986). The dominant trees and shrubs are *Amygdalus orientalis*, *A. korschinskii* (almond), *Pistacia atlantica* (pistachio) and *Crataegus aronia* (hawthorn). Undershrubs include *Artemisia herba-alba* (wormwoods) and various hemicryptophytes (plants which overwinter as rosettes) of the Lamiaceae family such as *Phlomis* spp. Terrestrial pollen records supplemented by deep sea core data offer additional evidence for the northwards extension of woodland-steppe during the Neolithic (see Hillman 1996; Rossignol-Strick 1999).

Open woodland communities such as park-woodland and woodland-steppe are far from stable in the area covered at different times, and in the relative proportions of trees and non-tree vegetation such as shrubs and grasses. Competition for water and soil conditions are the main factors responsible for this and have a direct effect on tree size and spacing, the development of lateral and/or vertical extensive root systems and woodland regeneration (Rackham 1998). Conversely, physiological adaptations and individual plant properties can influence vegetation structure and competition behaviour.

In addition to the factors discussed above, fire regimes, woodcutting, and livestock and wildlife grazing/browsing may affect vegetation types and the regeneration process (Scholes and Archer 1997). Hence, continuous grazing of herbaceous plants during the growing season may lead in the long term to the encroachment of grasslands by shrubbery, whereas woodcutting and fire usually reverse this trend to the benefit of perennial and annual grasses. On the other hand, wood cutting and intensive browsing in times of reduced herbaceous forage availability may result in the prevalence of stunted trees (Scholes and Archer 1997).

In addition to these factors, individual trees and shrub thickets usually attract wildlife by providing food from their seeds, fruits, twigs, leaves, flowers and buds, refuge from predators and adverse weather conditions, and a place to rear the young (Robinette 1972). Moreover leaf litter, faeces, fallen nest material and carcass remains enhance nutrient availability and thus facilitate vegetation regeneration and the development of species-rich biomes (Dean et al. 1999). In central Asia, similar conditions have been observed for the *Pistacia vera* woodland-steppe of Batghyz in Turkmenistan, near the borders of Afghanistan. There, in an otherwise bare landscape, dense stands of *Hordeum spontaneum* (wild barley) were able to grow around and in between pistachio trees, due to increased nutrient availability (G. Hillman, personal communication). Such highly specialised microenvironments could eventually turn into focal points in the regional landscape and thus become a major source of attraction for humans and animals alike.

Conclusion

The picture emerging from the botanical data warns against the uncritical adoption of present-day vegetation types as the potential "natural" or even "climax" formations, since modern analogues for past plant communities do not exist in the region. An attempt was made to overcome this problem through the judicious use of the archaeobotanical record, pollen evidence, geomorphological data and ecological analogues, in order to reconstruct the Neolithic woodland vegetation and delineate its diverse ecological settings. Further investigations will concentrate on the chronology of these preliminary results, by acquiring data covering the full timespan of Neolithic settlement.

Still, the degree to which such a reconstruction represents the "natural" environment as opposed to the anthropogenic landscape is debatable. From the earliest stages of settlement, human interference through woodcutting, herding and cultivating could have exerted a significant, albeit not always detectable by the standards of traditional palynological interpretations, impact on vegetation structure and its spatial and temporal transformations. Recent reviews of the pollen evidence from southeastern Europe and Anatolia (Willis 1995) have demonstrated that human-induced changes in woodland composition during the Neolithic should not be ruled out on the grounds that clear "anthropogenic indicators" (sensu Behre 1990) are conspicuously absent. On the basis of the archaeobotanical evidence, it could be argued that the gradual expansion of conifers otherwise attributed to climate factors such as the postulated drier conditions from ca. 8,000 B.P. (cf. Bottema and Woldring 1984) might likewise represent the result of intentional exploitation of oak woodlands for timber and/or browse. Similarly, the proportionally higher abundance of woody legumes, labiates and rosaceous shrubs such as cherries and roses towards the later levels of the settlement need not necessarily imply a substantial change in climate patterns. It could equally signify the gradual opening of broad-leaved woodlands and the establishment, within disturbed woodland patches, of shade intolerant taxa and/or the invasion of steppe grasslands by shrub communities due to their regular use as livestock grazing grounds. The detailed examination and quantitative analysis of charcoal assemblages from a wider array of archaeological contexts together with the consideration of the environmental and archaeological evidence and the existing ethnographic record, will serve as a basis for further research concer-ning potential strategies for woodland management and wood utilisation in south-central Anatolia during the Neolithic period.

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